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FROM: PROI (STINFO) 23 Apr 2001

SUBJECT: Authorization for Release of Technical Information, Control Number: **AFRL-PR-ED-AB-2001-101**
B. Chehroudi (ERC), Doug Talley, "Interaction of Acoustic Waves with a Cryogenic Nitrogen Jet at Sub- and Supercritical Pressures"

40th AIAA Aerospace Sciences Meeting & Exhibit **(Statement A)**
(Reno, NV, 14-17 Jan 2002) (Deadline: 11 May 01)

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PHILIP A. KESSEL Date
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Space and Missile Propulsion Division

ABSTRACT

Interaction of Acoustic Waves with a Cryogenic Nitrogen Jet at Sub- and Supercritical Pressures

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Combustion instability has always been one of the most complex phenomena in liquid rocket engines, and therefore difficult to fully controlparticularly in designing large output rockets. These difficulties stem from the emergence of oscillatory combustion with large pressure amplitudes. In one classification, high-amplitude, low-frequency (< several hundred hertz) pressure variations (or chugging) due to combustion is understood to be coupled with the feed line and structural modes of oscillations. Chugging is responsive to system-type analysis. Another instability is characterized by high amplitudes and high frequencies (screaming), and can lead to local burnout of the combustion chamber walls and injector plates. This is caused by extreme heat-transfer rates brought about by high-frequency pressure and gas velocity fluctuations, see *Harrje and Reardon [1]*.

To better understand the nature of the interaction between acoustic waves and injected liquid fuels in rocket engines, cryogenic liquid nitrogen is injected into a room temperature high-pressure chamber with full optical access on its four sides. The injection in this study is through a sharp-edged 50 mm long stainless steel tube with a 1.59 mm (1/16") outer diameter and a 254 micron (0.010") inner diameter with a length-to-diameter ratio of 200. Chamber pressure is changed from low subcritical values to supercritical values. To our knowledge, this is the first time such an interaction has been studied under supercritical conditions representative of high performance cryogenic liquid rocket engines. A specially designed piezo-siren capable of producing sound pressure levels (SPL) of up to 180 dB at its resonant frequencies (lying between 1000 to 8000 Hz) and at pressures to 2000 psi is used with a circular-to-rectangular waveguide to bring the acoustic waves into an interaction zone inside the chamber. The nature of the interaction between the acoustic waves and the jet under many different conditions (jet flow rate, chamber pressure, amplitude and frequency of the acoustic wave generator) will be documented by shadow imaging. Back-illumination and visualization using a model K2 Infinity long-distance microscope is used with a TM-745E high resolution (768(H) x 493(V) pixels in 8.8(H)x6.6(V) mm actual sensing area) interlaced CCD camera by PULNix to form images of the injected jets (for more details refer to *Chehroudi et al. [2]*).

It is found that a certain minimum oscillation amplitude is needed to bring about detectable interaction. When a rapid transition is made from below to above this minimum value, a strong and transitory effect is observed, characterized by eruption of many drops and ligaments from the surface of the jet combined with amplification of the surface wave instabilities. When set at its highest achievable amplitude, the oscillation augments the unstable surface waves and imposes a zigzag-shaped

contour to the jet. Preliminary results under subcritical condition indicates constriction of the jet in the acoustic propagation direction (perpendicular to the jet axis) near the injector exit followed by the acceleration of the atomization process further downstream. At supercritical chamber pressures, where no droplets were observed in previous studies, the effects is a shrinkage of the jet central "dark core" dimension both perpendicular to the propagation direction and in its axial length. However, the extent of the vapor phase appears to be increased, indicating enhancement in mixing processes. Figure 1 shows results at a subcritical pressure near the injector, excited at one of the piezo-siren's resonant frequencies (2700Hz) at the highest amplifier gain (producing the maximum acoustic amplitude). Figure 2 and 3 show similar results but at just below the critical and supercritical pressures.

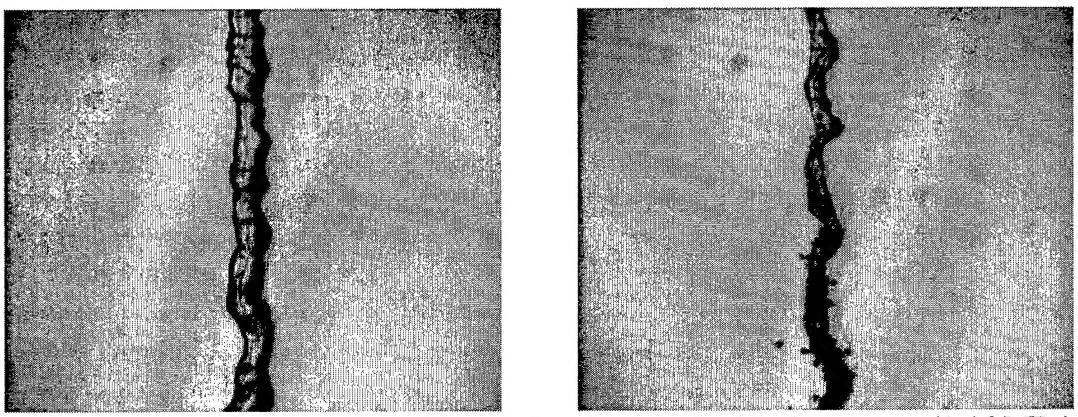

Figure 1. Cryogenic nitrogen injected into a chamber at subcritical pressure (1.46 MPa) and supercritical temperature (300 K). Acoustic wave propagation is from left to right and LN_2 flows from top to bottom. Left, acoustic excitation is off. Right, acoustic excitation is on at 2700 Hz and at a SPL of about 160 dB or greater.

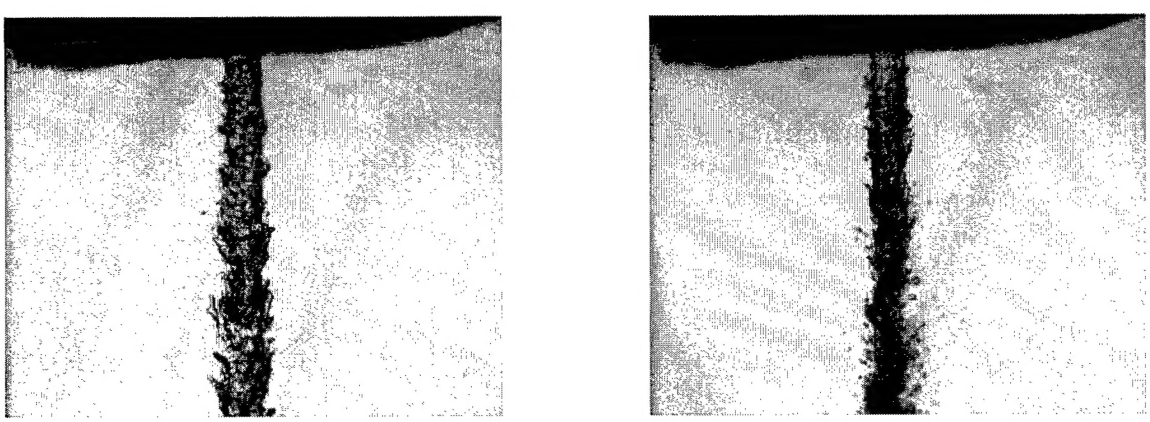

Figure 2. Cryogenic nitrogen injected into a chamber at near-critical pressure (2.48 MPa) and supercritical temperature (300 K). Acoustic wave propagation is from left to right and LN_2 flows from top to bottom. Left, acoustic excitation is off. Right, acoustic excitation is on at 2700 Hz and at a SPL of about 160 dB or greater.

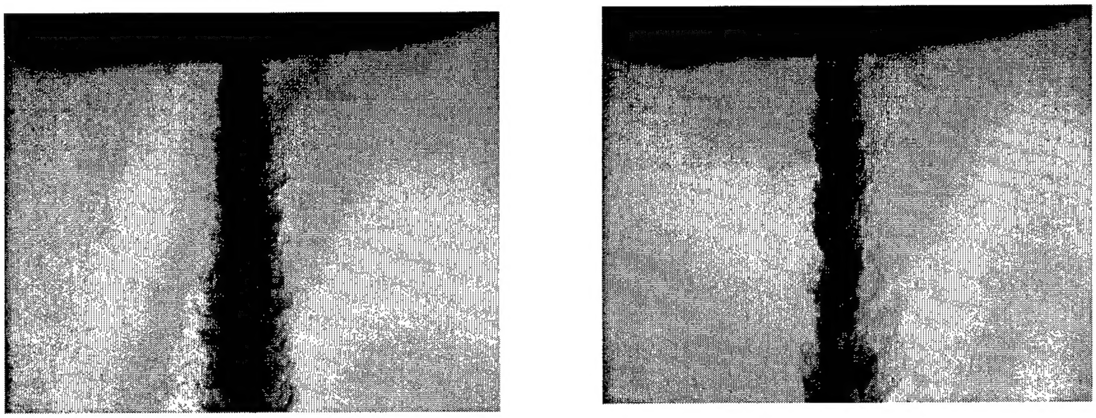

Figure 3. Cryogenic nitrogen injected into a chamber at supercritical pressure (3.5 MPa) and supercritical temperature (300 K). Acoustic wave propagation is from left to right and LN_2 flows from top to bottom. Left, acoustic excitation is off. Right, acoustic excitation is on at 2700 Hz and at a SPL of about 160 dB or greater.

REFERENCES:

1. Harrje, T. D. and Reardon, H. F. Liquid Propellant Rocket Combustion Instability, NASA report number NASA SP-194, 1972.

2. Chehroudi et al., 1999 Fractal Geometry and Growth Rate Changes of cryogenic Jets Near the Critical Point, 35th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, , 20-24-June, Los Angeles, CA, AIAA Paper n. AIAA-99-2489.